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Exploring the Psychometric Properties of an Instrument Developed to Measure Students' Views of Effective Mathematics Teaching at High School

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ABSTRACT The study reports the development of an instrument on the views about Mathematics Teachers' effectiveness. Following recommendations from literature on developing instruments, 186 items were initially compiled. This was eventually reduced to a 30-item instrument. The internal consistency of scores from the accepted instrument yielded an alpha value of 0.95. Based on this value reliability was acceptable. Construct validity was established through principal components analysis which yielded acceptable internal consistency alpha values for a six-factor solution. It is concluded that for a newly developed instrument, the results reported in this study are promising. The study recommends that the instrument should be administered in different contexts in order to consolidate and verify the psychometric properties reported here. Following the different studies, confirmatory analyses should then be computed.

INTRODUCTION

The purpose of teaching is to promote learning while the role of a teacher is to facilitate students' learning. Teaching entails designing appropriate activities meant to enable learners to develop and ultimately exhibit the expected learning outcomes. Research shows a strong link between effective teaching and students' academic achievement (Ko et al. 2013). In fact, the teacher's influence is one of the most important factors that affect learning (Ogbonnaya 2008; Sadler et al. 2013). This is because decisions that teachers make about their teaching can either facilitate or impede students' learning (Allen et al. 2013). It is in fact reported that some teachers are more effective in contributing to their students' learning than others (Desimone and Daniel 2010; Sadler et al. 2013). However, the challenge is to systematically explain the significant difference in teachers' skills and characteristics that account for the difference in their teaching effectiveness. This may be attributed to the scarcity in the South African context of reported valid and reliable instruments that measure teacher effectiveness in mathematics classrooms. Teaching effectiveness can be evaluated using teacher self-report, peer report and student report among other methods (Bergstrand and Savage 2013).

An important aspect of effective teachers is that they have good mastery of the substantive syntactic structures of the subject they teach (Tsang and Rowland 2005). In essence, effective teachers have a strong knowledge base of the subject matter content and a repertoire of pedagogical strategies that they can invoke in order to bring the lesson home to the students (Ko et al. 2013; Hill 2014). Such teachers need to be able to unpack the subject's content in a way that students would find meaningful. In other words, effective teachers have the ability to understand a subject well enough to present it in ways that students can establish a foundation of knowledge from and build on. This notion of effective teachers is in concert with the primary goal of teacher education that involves the disciplinary education through which subject matter content as well as pedagogical knowledge is acquired (Adeosun et al. 2009; Botha and Reddy 2011).

The focus in this study was on the importance of student evaluations of teaching effectiveness. It is pointed out that brilliant "… teaching reflects scholarship, personal integrity and

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ability to communicate with learners effectively" (Olatoye and Aanu 2011). In fact, students are direct recipients of the teaching and learning context. As a result, students are seen to be in a key position to provide information about teachers' behaviour in the classroom (Kyriakides et al. 2014). Evidence abounds that student ratings are a reliable and valid measure of the effectiveness of teachers' instruction (Kyriakides et al. 2014). It should be mentioned that not all student's evaluations are adjudged to be meaningful. On the contrary, some researchers have argued for instance that sometimes students' ratings do not seem to correlate with their achievement. In this regard, an argument is raised that it could be that most factors contributing to students' evaluations may be unrelated to a teacher's ability to promote student learning (Damron 1996). The arguments notwithstanding, the utility of student evaluations stems from the fact that students tend to offer meaningful feedback when they believe and know that their input will be valued by authorities (Chen and Hoshower 2003). This paper reports on the development of an instrument whose purpose is to determine students' views of the effectiveness of mathematics teachers at high school level, from a South African perspective.

Conceptualization of Effective Teachers in the South African Context

According to the South African Norms and Standards for Educators, teachers "… as agents of transformation of education are expected to fulfil the roles of being mediators of learning, interpreters and designers of learning programmes and materials, leaders, administrators and managers, scholars, researchers and lifelong learners, community members, citizens and pastors, assessors and learning area (subject) specialists" (South African Department of Education [DoE] 2000: 13). In a way, these roles form the hub of teaching effectiveness according to the department and it expects teachers to be able to fulfil them. This is in agreement with the view that effective teachers are those who through appropriate use of their repertoire of knowledge and skills achieve the teaching goals imposed on them by the authorities or the goals they established for themselves (Awang et al. 2013; Ko et al. 2013). In real terms then, it may be inferred that an effective teacher is one who facilitates the actualisation of the stated curriculum goals in the classroom. For mathematics teaching in particular, the South African mathematics revised National Curriculum Statement (NCS) envisioned, among other things, that "… the teaching of mathematics can help the students to recognise that mathematics is a creative part of human activity, develop deep conceptual understanding in order to make sense of mathematics, and acquire the specific knowledge and skills necessary for the application of mathematics to physical, social and mathematical problem" (DoE 2002: 5). In this instance, effective teaching of mathematics is about orchestrating the actualisation of the vision as expressed by the department.

The views as espoused by the DoE suggest that certain teacher characteristics are essential for effective teaching. A scrutiny of these reveals that the characteristics are complementary and interrelated. These characteristics may be grouped under knowledge of the subject; lesson preparation, organisation and presentation; effective student assessment and communication with the students. It is therefore these characteristics that when working in unison, assist a teacher to accomplish the curriculum learning goals. According to the South African curriculum statement (DoE 2002: 5) the conceptualisation of effective teachers in a sense assumes that:

- Effective teachers are masters of the subject matter.
- Effective teachers are aware of the students' intended learning goals (curriculum goals).
- Effective teachers possess skills which they combine with their knowledge of the subject matter, knowledge of the students' errors/misconceptions and knowledge of curriculum goals to accomplish the students' intended learning goals.
- The goals guide the effective teachers' planning and delivery of lessons.
- Effective teachers design appropriate learning units that are linked to the standards.
- Effective teachers actively pursue these goals. Hence, they set their teaching goals (directly or indirectly) to achieve the curriculum standards.
- Teacher effectiveness can be assessed in terms of students' behaviour and learning

Evaluation of Effective Teaching

Researchers in education have advocated various measuring instruments of teacher effectiveness. Among others, measuring instruments of teacher effectiveness have addressed issues relating to students' achievement; students' evaluation of the teachers' teaching; peer evaluation of the teacher; classroom observations; self-evaluations; lesson plan evaluations; evaluations of teaching portfolios and students' work-sample reviews (Doyle 2004; Berk 2005; Mathers et al. 2008). Among mostly measured variables, are students' evaluations of their teachers' effectiveness. This is the case because of the argument that students are the most qualified to provide valuable information regarding their teachers' classroom practices (Theall and Franklin 2001; Kyriakides et al. 2014). In this regard, it is pointed out that many studies (for example, Fauth et al. 2014) have reported high correlations between students' ratings of what is learned in a subject or their achievement in the subject and their overall ratings of the teacher's teaching. Also, younger high school students too have been found to be capable of judging effective teachers (Irving 2004; Kyriakides et al. 2014). Importantly, the reliability and validity of student ratings as a measure of teaching performance have generally been supported by research (for example, Beran and Rokosh 2009). For instance a review of the impact of student assessment of teaching on teaching quality has revealed that their assessments are among the most reliable and accessible indicators of teacher effectiveness (Prebble et al. 2004). It is further reported that student assessments have become a norm as an evaluative instrument (Zabaleta 2007). In fact, student assessments of teaching have been of such significance that in many instances they are used to make critical decisions (Beran and Rokosh 2009). In fairness though questions have been raised about the capability of student assessment of teaching to effectively give objective, dependable and accurate indication of what effective teaching entails.

Purpose

The purpose of this paper was two-fold. Firstly, it was to describe the development of an instrument meant to measure students' views about their mathematics teachers' effectiveness. Secondly, to provide evidence of the instrument's psychometric properties. That is, to report on the validity and reliability of the initial data obtained from the instrument. In respect of the latter, it is argued that "[S]tudent-test-based measures of teacher performance are receiving increasing attention in part because there are, as yet, few complementary or alternative measures that can provide reliable and valid information on the effectiveness of a teacher's classroom practice" (Kane et al. 2011).

Developing the Instrument

The researchers intended to develop a locally (South Africa) relevant student evaluation instrument designed to assess mathematics teachers' effectiveness from the perspective of their students. The main focus of the instrument was on teachers' mathematics mastery, lesson presentation, assessment and communication. In developing the instrument, the researchers were cognisant of Marsh and Hocevar (1991) suggested procedure that (a) developing a large pool of items (from literature, existing instruments, interview with students and teachers), (b) piloting the instrument to receive feedback about the items, and (c) considering the psychometric qualities of the items while revisions are made. Further, Berk (1979) suggests that a crucial first step in developing an evaluation instrument is to formulate a framework that specifies the domain of interest of a study.

It is pointed out that measurements will be valid if there is a "… continual interplay between theory, research, and practice" (Marsh and Roche 1997:1187). To develop the instrument, the researchers started with a literature search relating to characteristics of effective teachers and teaching. Specifically, the researchers searched for studies that surveyed students' and teachers' views of effective teachers such as that of Irving (2004). The researchers then perused official documents such as the South African Norms and Standards for Educators documents (DoE 2000), the National Curriculum Statement for mathematics (DoE 2003) and any other related literature. Finally, the researchers interviewed a non-random sample of Grade 8 to Grade 12 mathematics students and teachers. These participants were asked to indicate what their views were of effective teachers. From the literature review and participants' views, the following common expressions were extracted as descriptors of effective mathematics teachers: *excellent knowledge of the subject matter*; *ability to communicate the subject clearly*; *always attend class*; *helps learners where they don't understand*; *motivate learners to learn*; *gives learners opportunity to ask questions and talk in class*; *pays attention to students learning difficulties*; *prepares for lesson before coming to class*; *explains the subject well, provides helpful feedback to students*; *uses examples that students are familiar with to bring the lesson home*; and *provides relevant examples*.

Using the list of descriptors the researchers conceptualised a framework for evaluating students' views about effective mathematics teachers. The main attributes of the framework related to (a) knowledge of subject content, (b) lesson preparation, (c) lesson organisation, (d) lesson presentation, (e) assessment of students learning, and (f) communication with students. Looking through the lens of the framework and the descriptors of effective teaching, a pool of 186 items was developed. The 186 items were the exact statements and words used by the students and teachers and in literature to identify effective teachers.

For the 186 items, the researchers started a vetting process involving teachers, students and university based mathematics education specialists. The vetting process was carried out to ensure that the items were clear, had no ambiguity in meaning and they would be easily understood by the targeted respondents (Mogari 2004). Also, the researchers did not want an extremely long instrument that could end up unwieldy and take long to complete. Initially, the 186 items were scrutinised by six teachers (four mathematics teachers and two language teachers) and 10 high school students taking mathematics. It is worth noting that these students did not participate in the final study. On the main, the advice was to remove some of the items altogether. Also, some grammatical and nomenclature changes were recommended. For instance, it was suggested that the researchers use 'learners' instead of 'students' as this is standard practice in the high school system in South Africa. Following the suggestions the researchers trimmed down the total number of items to 135.

The researchers then requested four university based mathematics and science education researchers to examine the 135 items. They too felt the instrument was fairly long and suggested we trimmed it to 84 items. The researchers still felt an 84-item instrument would be long, so the items were given to seven mathematics teachers and three university mathematics and science education researchers. These persons had not seen the 84 items before. What was different compared to other vetting instances is that this time we added a Likert type rating scale against each item statement. Here, the instrument requested participants to rate whether the views expressed in each statement were true to them or not. The Likert type rating scale had seven points anchored by 1 = Is Not true to me at all and 7 = Is True to me all the time. This process revealed that a number of items were repetitive so some were eliminated resulting in a 50-item instrument.

The last method of selecting items for the instrument involved the computation of correlations between the average rating for each item and the total (summed) score across all items in each subscale (Trochim 2006). Following this author's recommendation all correlation coefficients between the two scores that were less than 0.7 ($r < 0.7$), were eliminated. This last process resulted in a 30-item instrument that we named Views about Mathematics Teachers' Effectiveness Questionnaire [VMTEQ] (item statements are depicted in Table 1).

Instrument's Psychometric Properties

In order to provide evidence of the instrument's psychometric properties both reliability and validity issues were addressed. The researchers explored the reliability of the instrument by computing the internal consistency of scores obtained by respondents (Cohen et al. 2007). Internal consistency was determined by Cronbach's (1951) coefficient alpha. Gliem and Gliem advise that when Likert-type scales are used "… it is imperative to calculate and report Cronbach's alpha coefficient for internal consistency reliability for any scales or subscales one may be using" (2003: 89). To ascertain validity we explored content as well as construct validity of the instrument. The following section provides the different steps we followed to ascertain the instrument's psychometric properties.

METHOD

Participants

Participants were from four schools in an education district in the North West province of South Africa. Two classes were originally chosen in each school for participation in this study. However, when the study was explained to the principal in the fourth school he requested that we selected a third class because this was the number of Grade 11 classes in his schools. In all a convenient sample of 165 mathematics students took part in the study. Of these, 56 did not fully complete the questionnaire. The researchers declared such questionnaires void where for instance, instead of selecting one option some students did not select any or selected two options. This means that we had a convenient sample of 109 students.

RESULTS

This study explored the psychometric properties of students' scores from the VMTEQ. The results are therefore based on the computations of reliability and validity.

Reliability and Validity of the Instrument

The reliability and validity of the instrument are reported in the section that follows. Here, internal consistency scores were computed as a measure of reliability of the instrument. On the other hand, validity is reported first from the perspective of content validity and secondly from a construct validity viewpoint.

Reliability

The internal consistency coefficient of scores obtained from the VMTEQ had an alpha value of .95 (95% CI: .94 - .96). Based on a rule of thumb this alpha value was excellent: " $\geq$ .9 – Excellent, $\geq$ .8 – Good, $\geq$ .7 – Acceptable, $\geq$ .6 – Questionable, $\geq$ .5 – Poor, and $\leq$ .5 – Unacceptable" (George and Mallery 2003: 231). We adjudged the scores of the participants on the VMTEQ to be reliable.

Validity

In terms of validity we established content and construct validity. Content validity of the VMTEQ was established by grounding the instrument on the conceptualised framework of effective mathematics teachers. To further ensure content validity the instrument was vetted by teachers, students and experts in the field of mathematics and science education. The experts were requested to check whether (a) each item in the instrument was about what it was meant to measure, (b) the scale was of appropriate length and (c) the language was appropriate for second language high school mathematics students. In fact, the process the researchers described previously in 'developing the instrument' in a sense details how the instrument's content validity was ensured.

In establishing construct validity, the researchers computed a principal components analysis. Here the researchers wanted to find out whether the instrument's items could be grouped according to the main attributes of the framework reported earlier. Specifically the researchers used SPSS ® version 19 to find out the nature of the resulting factors from a rotated matrix. To optimise the factor structure and search for the best explanation of patterns in the data, factor rotation (Varimax with Kaiser Normalization) was computed. In computing principal components analysis (PCA), the researchers first computed the values for Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. Cornish (2007: 3) explain these two computations as:

KMO is a statistic which tells whether you have sufficient items for each factor. It should be over 0.7. Bartlett's test is used to check that the original variables are sufficiently correlated. This test should come out significant ($p < 0.05$) — if not, factor analysis will not be appropriate.

In this study the value of KMO was 0.856 while Bartlett's test of sphericity was statistically significant ($p < 0.05$). These two values indicated that computing PCA was appropriate for the data (Field 2005). Table 1 shows the six factor solution from PCA with varimax rotation for the VMTEQ. Following Kaiser's criterion (Field 2005) the scree plot indicated a six factor solution was the best and this was supported by six factors with eigenvalues greater than unity. The six-factor solution accounted for 68.4% of total explained variance. This suggests that more of the variance is explained than the amount not explained.

Factor 1 accounted for 41% of the variance in the total factor solution. The 8 items compris-

Table 1: Five and four factor solutions from principal components analysis of the VMTEQ (N = 109)

	Items	*Factor*					
		1	*2*	*3*	*4*	*5*	*6*
Q 28	support lessons with useful classroom discussions	.763					
Q 23	give individual support to learners when needed	.751					
Q 24	adjust the lessons when learners experienced difficulties in learning	.750					
Q 17	make use of different teaching techniques	.696					
Q 27	take extra steps to help all learners learn and achieve success in maths	.691					
Q 20	help learners where they didn't understand	.622					
Q 26	explain something in different ways to help learners understand	.603					
Q 13	summarize the main points by the end of lesson	.467					
Q 5	simplify the subject matter to learners		.738				
Q 6	show sound knowledge of the subject matter		.704				
Q 7	show learners interesting and useful ways of solving problems		.653				
Q 9	end lessons by connecting to future lessons		.646				
Q 4	make lessons relevant and meaningful to learners		.595				
Q 3	give satisfactory answers to learners questions		.508				
Q 2	give definitions of terms/vocabularies that appear unfamiliar to learners		.653				
Q 22	are always punctual to class			.637			
Q 12	are always well-prepared for class			.560			
Q 15	relate ideas to learners' prior knowledge			.542			
Q 16	support lessons with useful class work			.517			
Q 10	present sections of the topic in a logical sequence			.478			
Q 29	give feedback to learners about their homework and assignment				.771		
Q 25	use assessment results to provide extra help to learners				.757		
Q 14	are always in class with all necessary materials for teaching topic				.507		
Q 21	encourage learners to learn				.410		
Q 18	motivate learners to pay attention to lesson					.773	
Q 1	introduce the topic in a way that captured learners' attention					.585	
Q 11	relate content to real life examples					.483	
Q 19	always attend classes					.787	
Q 30	communicate the topic clearly					.652	
Q 8	start lessons by connecting to previous lessons					.576	
Eigenvalues		12.29	2.40	1.97	1.46	1.35	1.07
Variance (%)		40.96	7.99	6.57	4.86	4.48	3.56
α		0.90	0.86	0.76	0.67	0.71	0.65

ing this factor primarily represented items relating to lesson facilitation (for example, Effective teachers are those that: support lessons with useful classroom discussions). Factor 2 accounted for 8% of the variance in the total solution and contained 6 items relating to knowledge of the subject (for example, Effective teachers are those that: simplify the subject matter for learners). Factor 3 accounted for 7% of the variance in the total solution and contained 6 items relating to preparation for lessons (for example, Effective teachers are those that: are always well-prepared for class). Factor 4 accounted for 5% of the variance in the total solution and contained 4 items relating to assessment (for example, Effective teachers are those that: give feedback to learners about their homework and assignment). Factor 5 accounted for 4.5% of the variance in the total solution and contained 3 items relating to motivating learners (for example, Effective teachers are those that: motivate learners to pay attention to lesson). Factor 6 accounted for 3.6% of the variance in the total solution and contained 3 items relating to communication with learners (for example, Effective teachers are those that: communicate the topic clearly). Table 1 further shows the alpha values for each of the factors. It is noticeable that the alpha values for Factor 4 ($\alpha = 0.67$) and Factor 6 ($\alpha = 0.65$) were close to being acceptable (George and Mallery 2003).

It is perhaps important to showcase how the factors interpreted from the factor analysis are related to and embedded in extant literature. In terms of the first factor that relates to classroom discussions, researchers have identified this as an integral aspect in teaching mathematics. For example, in its policy document: *Principles and Standards for School Mathematics* whose focus is on the classroom discourse, the NCTM calls for more student participation and talk in mathematics classrooms (NCTM 2000). Classroom discussions are also critical because they may allow a teacher to reflect on what was done in a classroom on a particular day. Furthermore, discussions may trigger a thought for a teacher on how an extant problem may be solved. This issue is illustrated in a study by Naidoo (2012: 4) who points out that one of the participants "… brought in an overhead projector transparency that she had prepared because of a class discussion during her previous mathematics lesson. This was evidence that she had reflected on her previous lesson (reflection-on-action)." While the virtues of discussion in classroom are currently emphasised, it has long been shown that these are more preferable in terms of promoting the long term (a) retention of information; (b) motivation of students towards further learning; (c) allowing students to apply information in new settings; and (d) development of students' thinking skills (Mckeachie 1986).

In terms of the second factor relating to knowledge of the subject, this is one of the most important issues in the teaching and learning context. It is reported that teacher quality is an important and critical determinant of student outcomes (Hanushek and Rivkin 2010). This suggests that teachers who lack subject matter knowledge will differ to those who possess this and therefore in how they impact on how their students learn and achieve in the subject. With regards to what mathematics teachers need to know, Hurrell (2013: 62) points out:

Mathematical Knowledge for Teaching (MKT) contributed to instructional quality, it therefore would not seem unreasonable to suggest that if we want to improve teacher effectiveness the development of MKT is an important factor. At the very least, familiarity with this construct would allow teachers to reflect on the various domains that require development to foster PCK, and allow them the opportunity to strengthen any areas in which they may feel they are deficient.

In terms of the other four factors, that is, relating to being 'well-prepared for class' (Factor 3); giving 'feedback to learners about their homework and assignment' (Factor 4); 'motivate learners to pay attention to lesson' (Factor 5); and 'communicate the topic clearly' (Factor 6): these are also critical in the learning and teaching context. Teacher preparedness is an important aspect of the learning and teaching context. This is because teachers that are not well prepared for lesson, may find it difficult to maintain order in a classroom or to encourage effective learning. This is illustrated by the fact that it is reported for example, that there is significant positive association between teachers' "self-efficacy in behaviour management, preparedness and classroom experiences" (Giallo and Little 2003: 21). Regarding behaviour management, it is argued that upholding this including the ability to maintain a productive learning environment is one of the essential skills teachers need to possess (Stoughton 2007). With regards to teachers giving feedback, communication, and motivation, all these are virtues that all those who teach should possess. These virtues are important because without them in a classroom context all learning may be affected negatively which may result in low achieving students.

CONCLUSION

The purpose of this paper was to develop a questionnaire and thereafter explore its psychometric properties. The developed questionnaire sought to elicit students' views about their teachers' effectiveness in teaching mathematics. A pool of 186 items formed the starting point of the questionnaire. The final instrument which was justified by statistical analyses is a 30 item instrument. The instrument was also found to be made up of 6 subscales namely: lesson facilitation, subject knowledge, lesson preparation, assessment, learner motivation, and communication with learners. In terms of the reliability of scores from the instrument this was found to be excellent. However the internal consistency scores of the subscales ranged from acceptable to excellent. The researchers also ascertained the instruments' validity through content and construct validity. For the former a number of referrals to students and professionals were undertaken for their judgment. For the latter principal components analysis with varimax rotation indicated a six factor solution with 30 items.

RECOMMENDATIONS

The results as reported in this paper are promising. It is however important to note that these results are only preliminary. This means that there is need to administer the Views about Mathematics Teachers' Effectiveness Questionnaire (VMTEQ) among different mathematics students in different contexts in South Africa. Conducting different exploratory studies has the potential of further enhancing the psychometric properties reported in this preliminary study. Following the number of exploratory studies there will be a need to confirm the factor structure of the VMTEQ. This will be done by conducting a confirmatory analysis wherein the six factors constituting the instrument will be verified together with their underlying latent constructs. Also, when this study is carried out among different mathematics students in different contexts in South Africa a number of alpha values (reliability scores) and validity computations from the questionnaire will be available. An important aspect of those alpha values is that they may be combined in order to compute the reliability generalization of the questionnaire.

LIMITATIONS

This study was conducted following appropriate research methods and data analysis but some limitations are worth acknowledging. Here, the instrument was developed by the authors, which suggests that it may not be the most efficient and succinct instrument at this stage. This means that the instrument will need to be refined in order to reach an optimal point in terms of collected data. Data were collected from 165 participants from only four schools in one South African province. However, even though the sample was adequate for conducting the statistical analyses computed here, it could not be described as coming from a nationally representative sample of students. It is therefore not possible to generalize the findings to all students and all schools in South Africa.

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